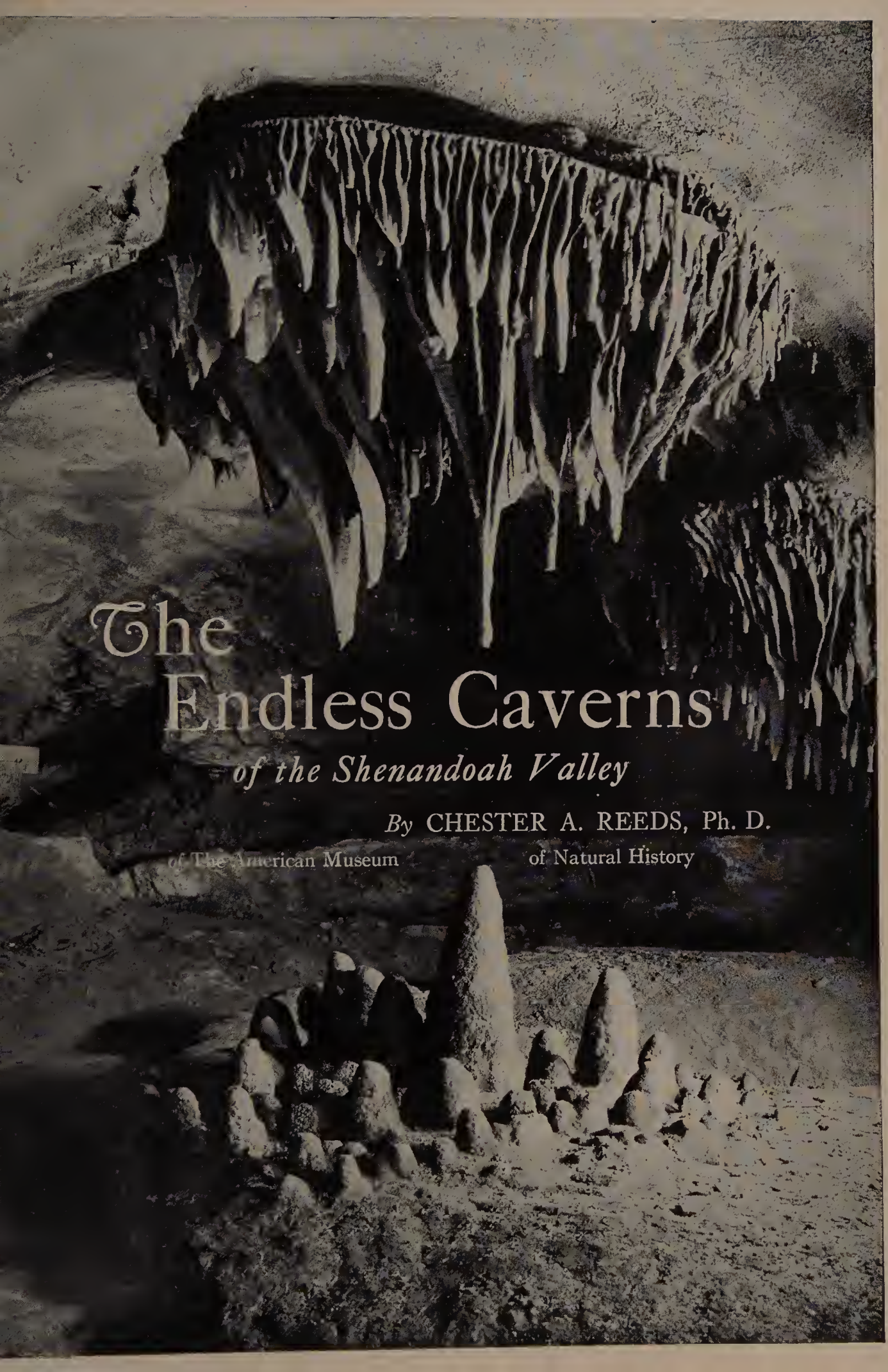

The Endless Caverns

of the Shenandoah Valley

By CHESTER A. REEDS, Ph. D.
of The American Museum of Natural History

The Endless Caverns

of the

SHENANDOAH VALLEY, VIRGINIA

By Chester A. Reeds, Ph.D.

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American Museum of Natural History, New York.

Foreword

In the preparation of this booklet the author has endeavored to present in a simple and understandable way a brief resumé of the present knowledge concerning the origin and development of the Endless Caverns. The geological history of these caverns is so closely related with that of the Shenandoah Valley that a short account of its evolution has also been included. The work of Watson and Cline, in 1913, on the 'Drainage Changes in the Shenandoah Valley' has been especially helpful in tracing the natural history of the Valley.

This little booklet was written in response to the numerous questions which have been asked concerning how the caverns were formed. The author has attempted to answer these queries by the use of text, pictures, and explanatory notes. The booklet contains information on caves that is of interest not only to teachers and students, but also to the general public.

The author is indebted to the following gentlemen for the opportunity of visiting the Endless Caverns in January, 1925: Mr. Henry Collins Walsh, of the Explorers Club, New York; Mr. George H. Sherwood, Acting Director of the American Museum of Natural History, New York; Colonel Edward T. Brown and Major Edward M. Brown, owners of the Endless Caverns, New Market, Virginia.

C. A. R.

11 Wellesley Avenue,
Yonkers, New York.

April 24, 1925.

A PORTION OF THE SHENANDOAH VALLEY, NEAR THE CEDAR CREEK BATTLEFIELD.

The undulating character of the Shenandoah limestone with its sink-holes, fields, and forested areas is well shown in the foreground. The Massanutten Mountain capped with a resistant sandstone appears in the background. Throughout its extent it is noted for its even crest line, occasional wind gaps, and forested surface.

THE ENDLESS CAVERNS

of the

SHENANDOAH VALLEY

An Account of

The wonderful work of water

with

Special Reference as to how the Caverns
and the Shenandoah Valley were formed

by

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American Museum of Natural History
New York

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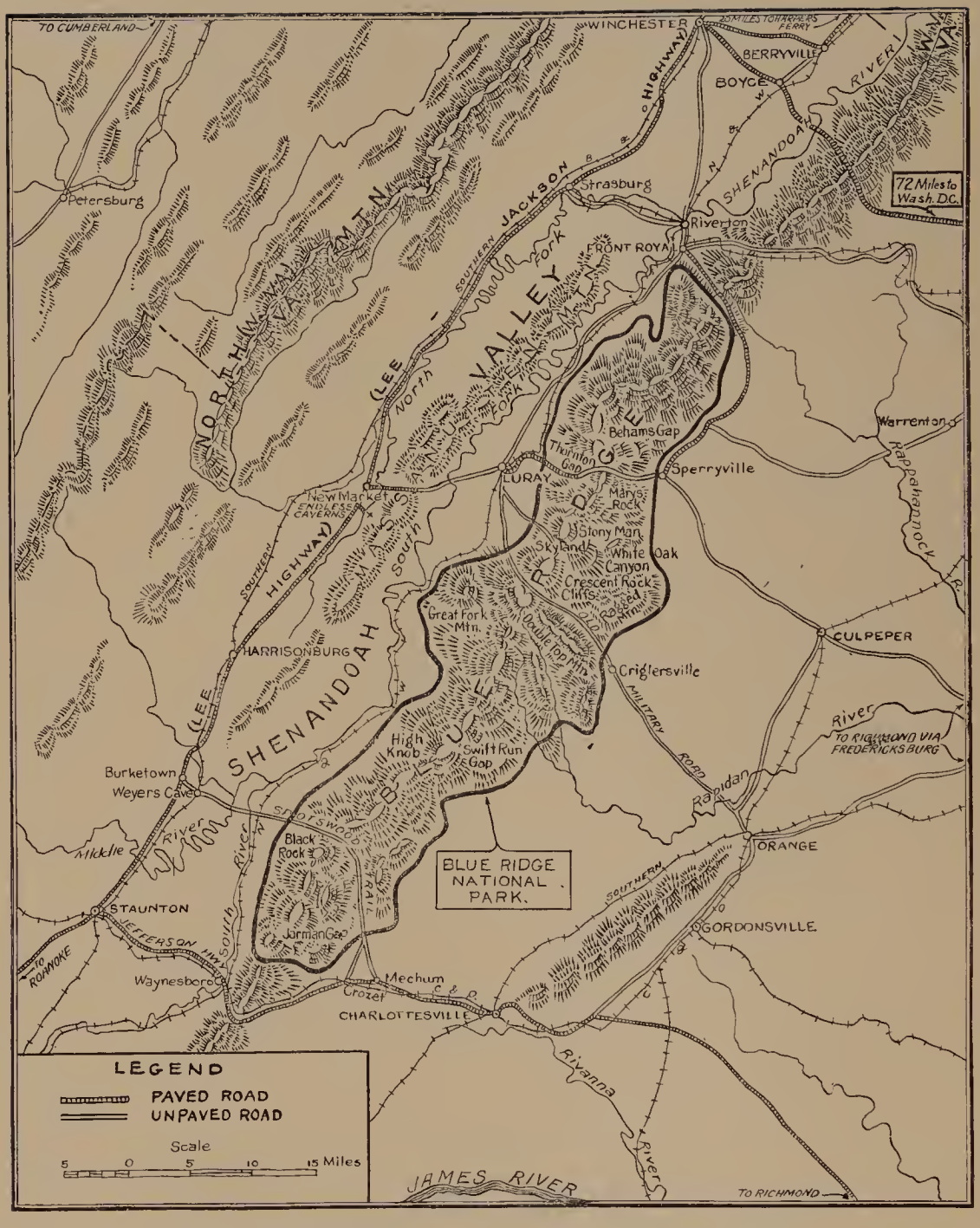


LOCAL MAP OF THE REGION ABOUT THE "ENDLESS CAVERNS"

When the tourist attempts to visit one of nature's remarkable exhibits of her handiwork, such as the Endless Caverns, he is often confronted with the question how to get to the place. This sketch map of the highways leading to the Endless Caverns has been prepared to meet this query. The "Endless Caverns" are two miles south and two miles east of New Market, Virginia, at the end of an excellent road. New Market may be reached by the Southern Railroad or Chesapeake & Ohio, via Staunton, Va., out of Washington, D. C., or by motor car over the well paved pike which leads down the Shenandoah Valley from Winchester to Staunton. The picturesque Massanutten Mountain which rises fifteen hundred feet above the valley along its eastern margin lies just back of the Endless Caverns.

ENTRANCE TO THE ENDLESS CAVERNS

This rustic stone house set in a grove of virgin trees on the side of Cavern Hill is the inviting entrance to the Endless Caverns. In 1879, two boys chased a rabbit to this site. The rabbit disappeared under some stones and when the boys removed the rocks they discovered a passageway leading to the unknown caverns. In 1920, the natural opening was enlarged, improved, and access made easy.

INTRODUCTION

THE CAVES of the Shenandoah Valley, Virginia, are famous throughout the world. Every year thousands of people visit them to view nature's handiwork underground. These caverns contain features which are peculiar to the region and are so wonderful from the standpoint of original and secondary formations and natural color effects that they well repay anyone of the forty million people that reside within two days' motor journey the small outlay of time and money involved in going to see them. Various caves have been explored and made accessible to visitors in the Shenandoah Valley, but the Endless Caverns at New Market, Virginia, constitute the most attractive series of chambers that I have examined. Going through them with the aid of that modern illuminant, electricity, and well-informed guides, is like reading one of the best novels or short stories, for with all obstructions to one's progress removed along one and a quarter miles of well-lighted pathway, one can devote his or her entire attention to the phenomena exhibited. There are surprises and pleasing effects on every hand

A SINK-HOLE

Funnel- or saucer-shaped depressions are often seen in limestone regions. They are called "sink-holes." Rain water, which drains into them, is lost sight of until it reappears in subterranean streams. Sink-holes also play an important part in the ventilation of caverns. The orifice is oftentimes surrounded or studded with trees.

with a masterful climax at each of the principal turning points in the cavern journey.

The development of these caverns in thick beds of limestone is attributed principally to the work of underground water. Such water is derived from that portion of the rain- or snow-fall which does not run off or evaporate but which soaks into the ground. In its passage through the air this water absorbs carbonic acid from the atmosphere and from the vegetable cover before it passes vertically down through the interstices and joint-planes in the rock. On reaching the ground water table, which may be a hundred or more feet below the surface, the water flows laterally along horizontal courses in directions that simulate the surface drainage, but the underground channels are not so well defined nor are they as regular as those above ground. The limestone being solvent in the presence of water containing carbonic acid, underground passageways are dissolved out of the natural rock forming caverns. As the main drainage streams on the surface cut their channels deeper into the landscape, the underground streams do likewise: but they never cut below the master outdoor streams, for the cave waters flow eventually into the principal rivers of the region.

From this we see that the streams that drain the caverns and those that drain the land are connected. Since the history of both the caverns and the landscape is

SOLUTION AND EROSION UNDERGROUND

The Endless Caverns afford numerous examples of the solution effects produced by swiftly moving carbonated waters. On the left of this view is an enlarged joint-plane which has been widened by rain-water passing down from the sink-hole above. The smooth shelf or terrace on which the author sits has been carved out of the natural rock by the underground stream. The rough, irregular pendant masses on the ceiling have also been etched by the acidulated waters out of the virgin rock.

revealed by the work of water it is natural for us to examine the evidences of this action (1) below ground, and (2) above ground.

The Work of Water Below Ground

As stated above the underground water is derived from that portion of the rainfall or snowfall which soaks into the ground. Rain water in its passage through the air dissolves notable quantities of carbon dioxide and oxygen, with minute amounts of other substances and is thus equipped for doing chemical work. This water in passing through the soil of fertile or forested areas such as the Shenandoah Valley absorbs additional carbon dioxide and also organic acids derived from decaying vegetation. In limestone regions such as this the absorbed gases give the water a singular capacity for taking into solution a large amount of lime and iron, leaving behind only the insoluble impurities, usually clay which forms the reddish or yellowish soils. It has been estimated that the land surface of the globe is lowered one foot in 30,000 years by the solvent action of rain water. It is more rapid than this in limestone areas such as the Shenandoah Valley.

FORMER SUBTERRANEAN STREAM COURSES

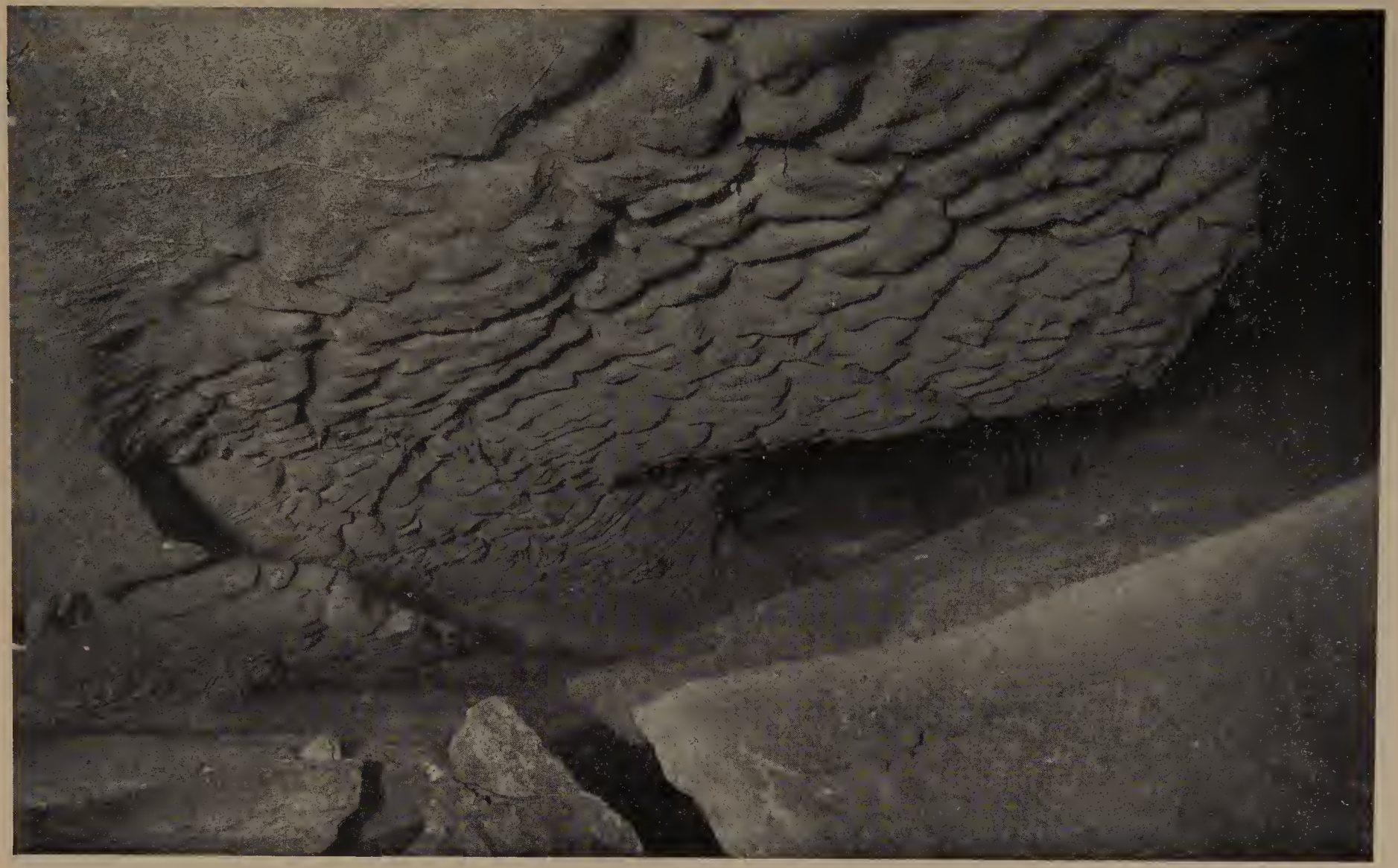
The abandoned stream courses of the Endless Caverns arouse the interest of every visitor. The circular outline of one of them engraved on the ceiling is shown very clearly in the upper portion of this view. A profile-section of the same stream at a lower level appears in the huge limestone block in the left central section of the picture. After this structure was carved, the huge block containing it was separated along a joint-plane, followed by undermining, tilting, and sliding of the block. A passageway now appears between the two masses of rock.

UNDERGROUND CHANNELS AND PENDANT FORMATIONS

This view gives another glimpse of the tortuous and uneven character of the channels in these old subterranean rivers. Some surfaces are smooth and terraced; others of curious design have been carved out of the natural rock and left suspended from the ceiling. The longest pendant is a stalactite.

THE CONFLUENCE OF TWO UNDERGROUND STREAMS

Old stream channels have been remarkably well preserved. Their abandoned courses afford different routes for visitors through a portion of the caverns. The portals of two old streams may be seen to the right and the left of the central mass of rock. Joint-planes which have been filled with calcite but not yet opened up to the pronounced movement of underground waters are shown as mere lines on the ceiling. The more recent secondary formations are represented by stalactites, stalagmites, and corrugated ribbed-like developments on the floor of the cavern. Note the cups in the row of stalagmites on the floor at the right.



THE ANGEL'S WING

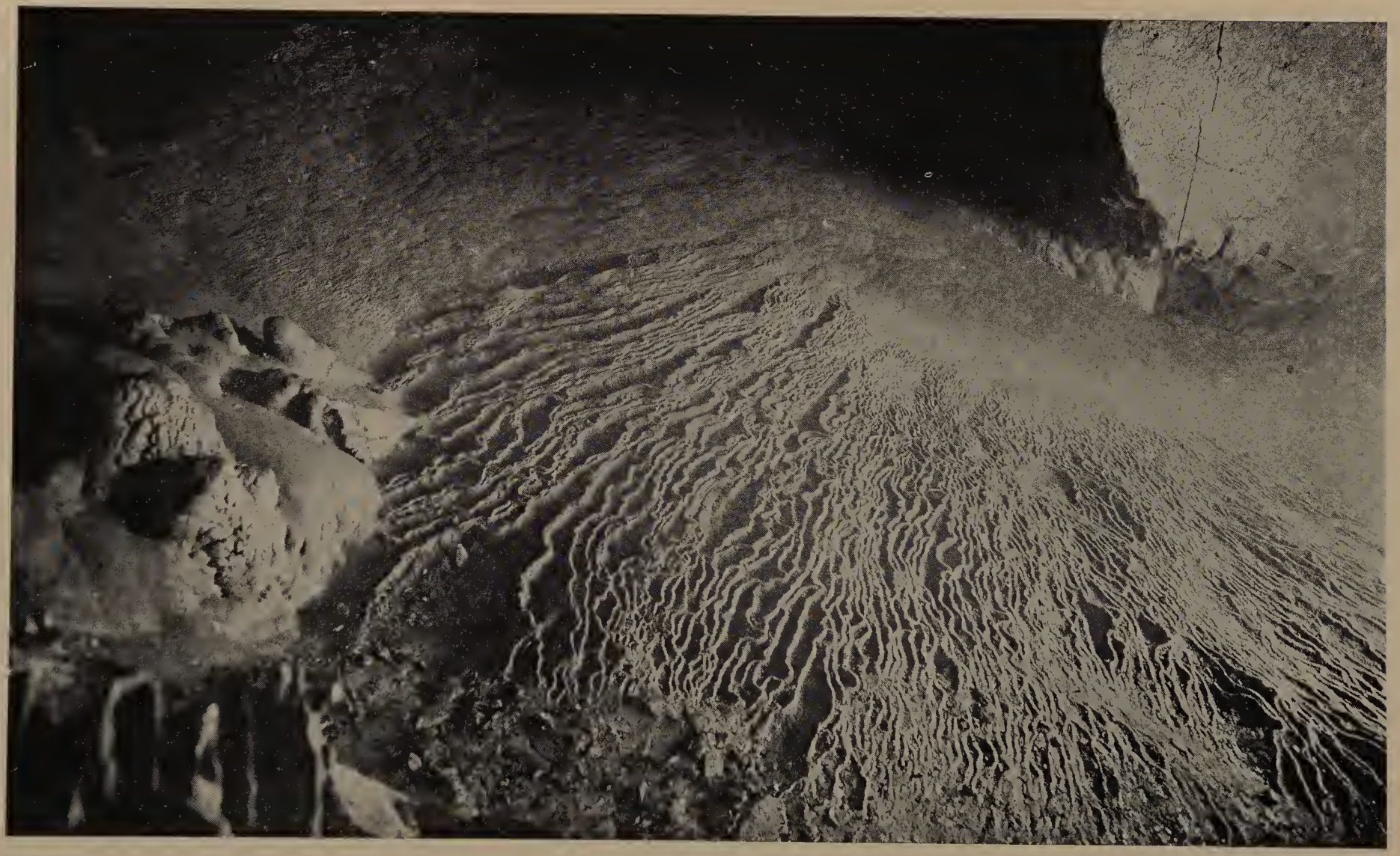
The acidulated waters which coursed through the underground passageways of the Endless Caverns in past ages etched many a curious design on the ceiling. One of the most beautiful patterns of this nature is the exhibit called the Angel's Wing.

THE ENTRANCE TO SKYLAND

Stalactites are here arranged in a pleasing drapery effect along an enlarged joint-plane. The presence of a considerable mass of flowstone in the lower central portion of the view indicates that the stalactitic stage has reached its zenith, for instead of dripping and evaporating slowly as in the formation of stalactites, the watery solution flows over all exposed surfaces to the point where evaporation equals the supply.

THE GATEWAY TO FAIRYLAND

It is a pleasure to walk through such an entrance to Nature's own underground fairyland. Numerous stalactites of varied shapes and hues adorn the ceiling in the left foreground, while in the distance great sheets of smooth flowstone cover the uneven surfaces.



THE MARINE CORRIDOR

Out of the stygian darkness a great sheet of flowstone extends towards you. It appears to represent the downtrodden ground in front of the lair of a great dragon. But we hear no sounds and walk lightly across the upturned shreds of a surface which has apparently been torn apart by the claws of the hidden monster. This delicate structure is not as hard as granite; nevertheless thousands of visitors have crossed this threshold to the Bronze Room without producing any ill effects on these ridges of calcium carbonate which are allied to those in the "Lily Pads" exhibit.

A SCENE IN THE BRONZE ROOM

This is a composite view. The solution effect of acidulated waters is shown on the left wall while secondary formations appear in the right portion. "Lily Pads" are noticeable in the left foreground. With its oriental color variations and spaciousness, the room produces an effect that is pleasing to the visitor.

THE TWIN COLUMNS

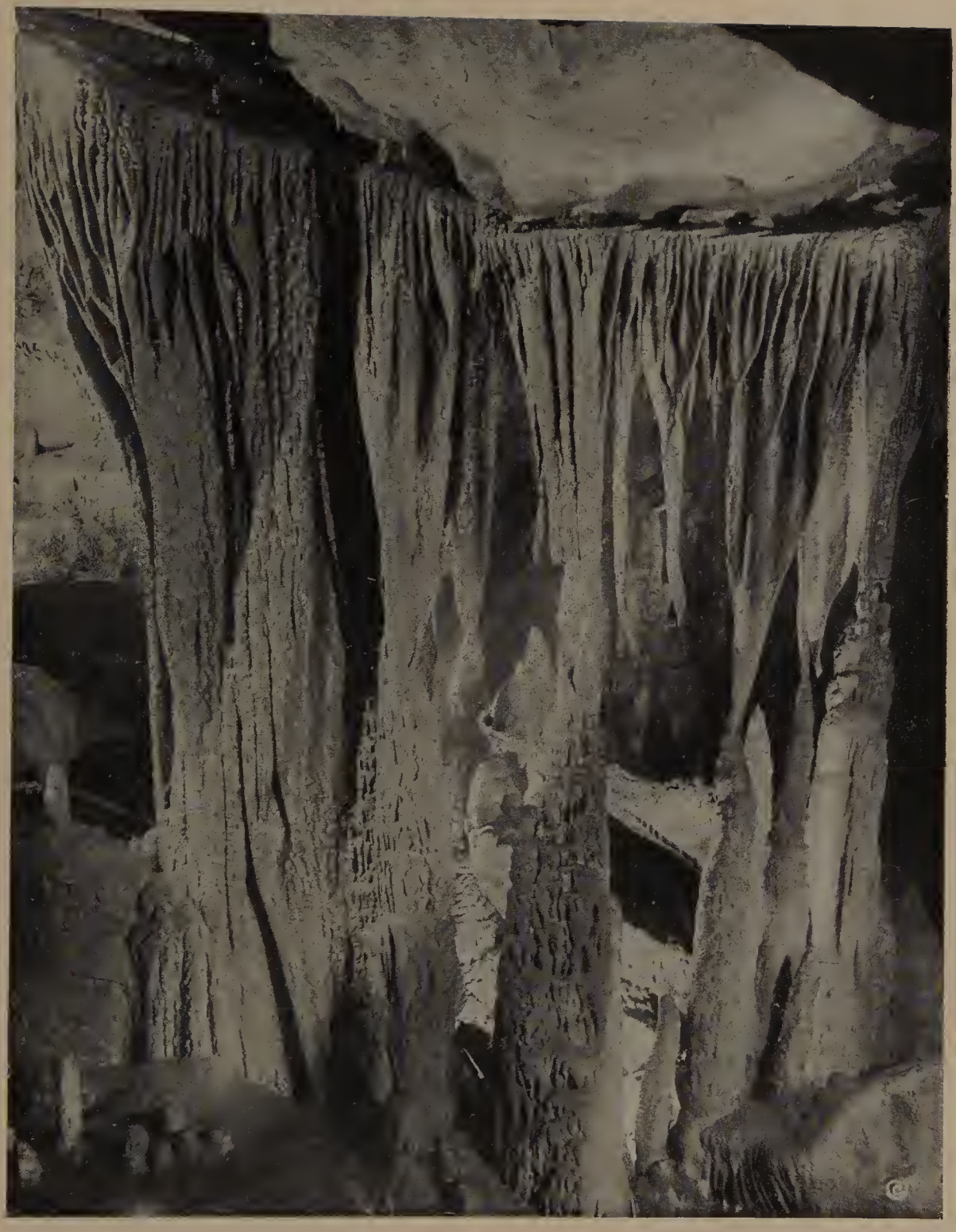
These huge columns are connected with the early history of the enlarged joint-planes which appear in the natural rock above them. The later history of this section of the cavern is revealed by the immense masses of flowstone in the lower and right foreground. This flowstone is so thick that it has bridged over a large chasm below. Cascades of flowstone are also shown in the left portion of the picture.

THE SNOWDRIFT

This is one of the most beautiful exhibits of flowstone in the Endless Caverns. The flowstone has been precipitated from the watery solution which entered the cavern through a large opening in the upper right corner of the view. It has built not only a white stone cascade but also conical masses on the cavern floor. A small grotto has been formed behind the snowdrift. The original rock dipping to the east appears in the background.

PHYSICAL FORCES AT WORK IN THE BRONZE ROOM

The author is examining a healed crack in a secondary shield formation. Open cracks were observed locally in other places. They suggest earthquakes, but their local distribution implies that they have been formed by the shrinkage of underlying cave earth following loss of water content or settlement under the weight of huge columnar masses of lime carbonate. In the process of recementation as noted here, raised welts have been left. They are composed of the same material as the shield, but of a later deposition.



THE GYPSY TENT

Another attraction in the Endless Caverns is the Gypsy Tent. Nature has woven here a design for a child's playhouse with plenty of windows and strong supports. Originally there were two great shields with spikes, set face to face, but Nature has been so long in building it, centuries in fact, that the cones have joined to form columns. The supply of material has been so abundant of late that flowstone has been added to the outer surface of the supports in such a manner as to produce an open lace-like effect.

THE "DIAMOND LAKE"

Every visitor who enters the Endless Caverns should go far enough to see this unique exhibit. It is at one of the main turning points in the cavern journey. Its presence is not detected until the guide raises his electric wand and you see the long red and yellow rays of dawn light up the view. While you stand in close proximity admiring the ever-changing aspect of this diminutive crystal lake, you suddenly realize that it is noonday. Time passes quickly, evening appears, and the approach of twilight suggests that it is time to go home. The guide lowers his wand and the lake vanishes.

THE PALACE OF THE FAIRIES

Before leaving the "Diamond Lake" the guide bids you face about and enjoy a distant view of a diminutive palace, the home of the fairies, set in a long narrow space out of harm's way. The architectural features are so wonderful and Nature's modeling so exquisite and delicate that one is reluctant to leave. By special permission of the owners the author was permitted to investigate Nature's handiwork at close range. Never will he forget his impressions of being in a real Palace of the Fairies.

A FOUNTAIN OF YOUTH

Here all thirsty visitors pause for a refreshing drink of water. Such a fountain we do not find anywhere else, for it represents a combination of stalactites and stalagmites arranged in the manner of great shields with the spikes set face to face. The lower ends of some of the pendant stalactites on the upper shield have been broken off so that the underground waters run down through their hollow interiors and drip into a large basin. This drip affords drinking water of excellent quality. Two of the stalactites and their corresponding stalagmites have joined together, forming columns. The water which originally ran down through the tubes of the stalactites to their tips now passes over the exterior surface of the columns to produce flowstone.

THE GIANT SHIELD

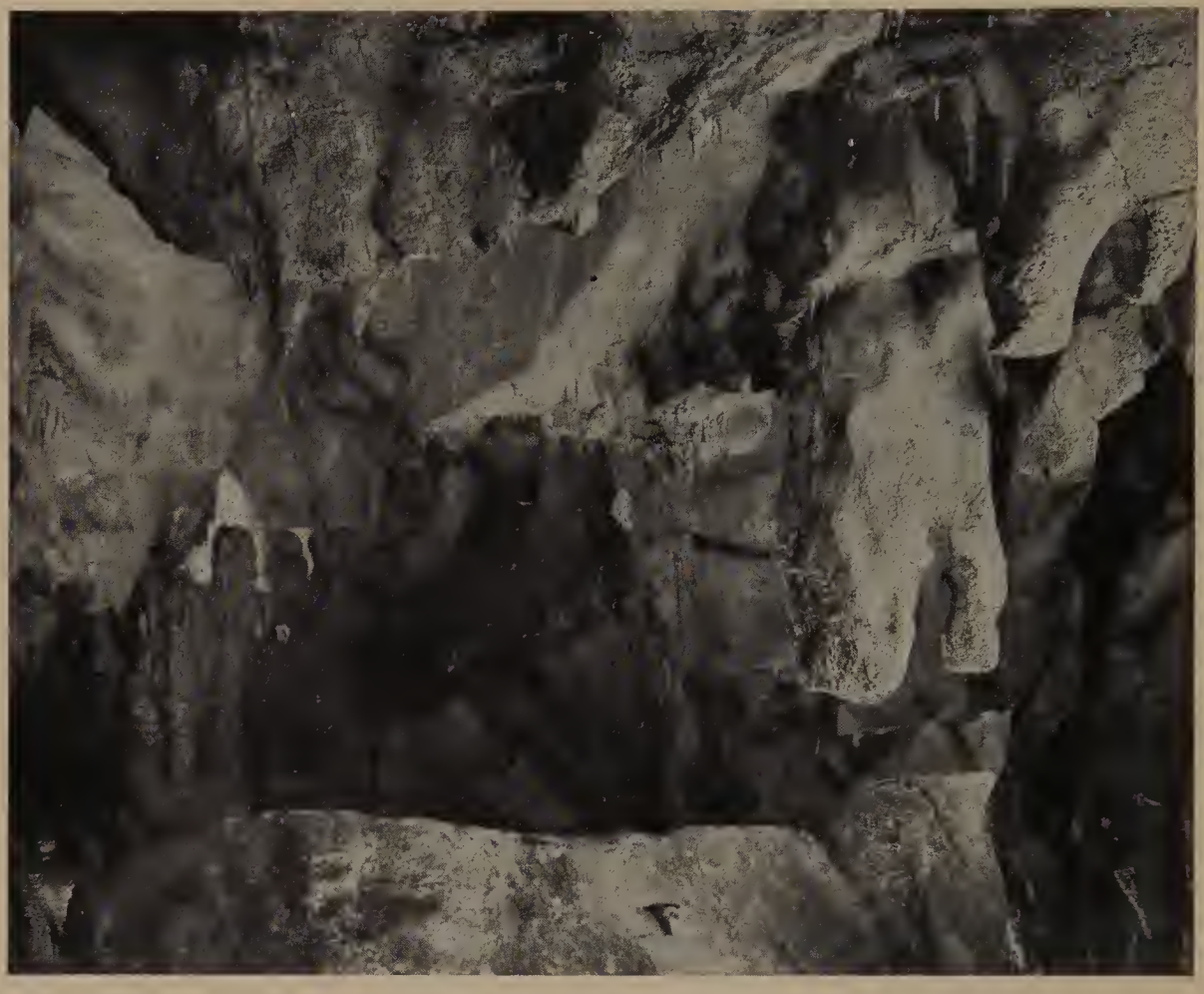
What great warrior thrust this great shield so deep into the ground that it stands upright? It is an excellent example of dripstone. From its rounded and thickened upper margin it appears to have been formed about a seam on the ceiling of the cavern. When its size increased many fold the supports gave way and it dropped to the floor. When it fell the many pointed stalactites were thrust so deep into the mire that the giant shield remained upright in position. Since then the surface of the ribbed and fluted stalactites and the floor of the cavern have been covered with flowstone.

THE UNDERGROUND CATHEDRAL

Here is a display that is simply marvelous. Evidently Nature has extended her hand to show man that she can produce something that he cannot duplicate. Man has neither the patience nor skill to attempt an exhibit of this kind. If he used the natural method, he would not live long enough to see his work finished. If he tried an artificial method his finished product would not be so graceful and artistic as Nature's. To sense the wonderful color effects that Nature has cast over this exhibition of her handiwork, it is necessary for the spectator to visit the Endless Caverns.

SURVEYING THE ENDLESS CAVERNS

Dr. Chester A. Reeds and Assistant Mr. E. J. Foyles at work in Alexander's Ball Room. Level and traverse lines were run throughout the length of the electrically lighted section. A pendant mass of natural rock some 90 feet in circumference and reported to weigh 500 tons appears in the central background. Extensive explorations were also made along the dark subterranean stream 100 feet beneath the Ball Room.



THE MITTEN ROOM

One of the unforgetable features of the Endless Caverns is "The Mitten," a great pendant mass of natural rock which the underground waters left behind to greet every visitor who enters the caverns. It hangs near the entrance. Its welcome grasp leaves a firm impression upon the mind of the curious and a reassuring greeting to the timid.

The chemical reactions which take place may be stated briefly as follows: Limestones are composed almost entirely of calcium carbonate, $CaCO_3$, and are rarely soluble in pure water, but when carbon dioxide gas, CO_2, composed of one atom of carbon and two of oxygen, is dissolved in it there is formed a watery solution of carbonic acid, H_2CO_3. This attacks the limestone and converts it into calcium bicarbonate, $H_2Ca(CO_3)_2$ which is quite soluble in water but is unstable in the presence of the air of caverns or of the atmosphere. Water containing such material in solution is commonly referred to as hard water.

Descending through the soil, this solvent compound of water and carbonic acid gas finds its way into the narrow crevices or joint-planes which extend in three directions generally, forming rude cubes, in the rocks of the earth's surface. These joint-planes are developed by the alternate expansion and contraction of the rocks due to daily and seasonal changes of temperature. In limestone areas the gaseous solution slowly widens these joint planes until they are so spacious that the streams desert the surface and flow under ground. At first when the crevices or joint-planes are narrow the excavation is done by the dissolving action of the water;

STALACTITES OF DIFFERENT AGES

Where the rain-water charged with carbonic acid seeps slowly down from the surface along any one of the numerous joint-planes in the rock it dissolves the limestone and carries it in solution. On reaching the roof of the cavern the excess of carbon dioxide in the watery solution escapes in the presence of air. This causes the lime in the water to be precipitated in the form of icicle-like projections called stalactites. They develop very slowly as there is only a little lime in each drop of water. In the above view some of the stalactites are small and youthful, others are large and old, representing hundreds of years.

but when it has thus excavated a channel or sink-hole sufficiently large to permit a stream to flow freely through it, the velocity of the current through the new-found way abrades the rocks by its mechanical power, at the same time the water exercises its solvent action.

In the Endless Caverns there are many fine examples of rock terraces, pendant formations, scalloped and fretted surfaces, besides the large chambers and passageways carved from the natural rock, that bear witness to the excavating power of the underground streams. The pendant formations etched out of the original rock are not only curious to behold but when the guide taps them gently with a stone they are resonant, and give forth beautiful musical tones when played upon.

In all probability that portion of the Endless Caverns which has been opened to the public was developed when the surface relief was slight, the run-off poor and the underground drainage prominent. Subsequently the Shenandoah Valley plain

WHERE NATURE JOINS HANDS

Curtain or drapery effects may extend across a room where the acidulated waters have opened up a joint-plane. If the evaporation of the carbon dioxide from the tip of the stalactites is not rapid enough to take care of the supply some of the solution drops to the floor to form the blunt-tipped stalagmites. Columns or pillars are formed by the joining of stalactites and stalagmites. If there is an excess of the watery solution it flows down over the surface of the stalactites, stalagmites, and columns, and spreads out over the adjacent floor of the cavern, forming flowstone, as noted in the above view.

was elevated several hundred feet, the caves raised, the old courses drained and new ones formed at lower levels for the underground streams do not now flow in the upper level. With the uplifting of the region the deposition of the secondary deposits such as stalactites and stalagmites began in a conspicuous way in the upper caverns, and has continued for centuries down to the present time.

The secondary deposits are formed by a modification of the very same action that produces the cavern chambers. When the water charged with carbonic acid finds its way through an open channel, it dissolves the rock and bears the lime speedily away; when, however, the water has to creep through narrow interstices or crevices, it advances very slowly and in small quantities, until it reaches the space of a cavern. Then it oozes, drop by drop, from the narrow joint-planes which are evident in the roof or ceiling. As there is constant, though slow, circulation of air through these caverns, the exuding water may evaporate without falling to the

THE ROOM OF THE SLEEPING GIANTS

In this view one sees the etched ceiling of natural rock, on the right, rows and clumps of stalactites with corresponding stalagmites below; at the left and in the center great masses of flowstone have partially concealed huge columns, stalactites and stalagmites. The visitor does not linger long here lest he disturb the sleeping giants, their beds are clearly discernible on the left.

floor, leaving where it dries the various dissolved substances which it contains. In this way a slender, icicle-like body called a stalactite begins to form on the ceiling, and grows with varying speed toward the floor. If the incoming water is greater in quantity than can be taken up by the air, it drops from the hanging stalactites. When it strikes the floor the drops are shattered. Evaporation and the loss of the carbonic acid in the air causes a still further deposition of the dissolved matter, which crystallizes in a conical heap, known as a stalagmite. Year after year this solid cone grows slowly upward towards the corresponding descending cone. When they meet they form a column known as a pilaster. As the water commonly penetrates, not at one point but along the various intersecting lines of joint-planes the stalactites may assume the form of coalesced columns, or sheets, which in time form a continuous drapery that may extend entirely across the space of the gallery. If there be many joint-planes in the roof, the gallery may in time become quite filled by the conjoined sheets of stalactitic material. This is particularly noticeable in the Underground Cathedral. This process of depositing lime

THE SHAH'S HAREM

This room is oriental in its color and decorations. On the ceiling bosses of natural rock with secondary pendant stalactites protrude beyond the scalloped surface. Many stalactites of various sizes, circular draped shields, huge columns and stalagmites more or less covered with flowstone appear in an artistic setting against a background of gray limestone in which the lines of stratification are perceptible.

goes on most actively in the upper or oldest levels of the cavern, for the reason that they are nearest the surface and close to the supply of carbonated waters. The lower levels of the system of caves are generally destitute of them, the percolating water having found its way only into the upper chambers.

It is interesting that so small a circumstance as the speed with which the water flows through the crevices in the rocks can thus profoundly affect the method of its action. Where it goes swiftly, it excavates the caves; where it moves slowly, it tends to obliterate them by depositing stalactites and stalagmites and other secondary deposits in the presence of air. This is due to the fact that the calcium bicarbonate is an unstable compound in the presence of air for under such conditions the CO_2 molecule is readily given off into the cavern causing a precipitation of the remaining calcium carbonate in the form of stalactites, stalagmites, sheets of onyx, flowstone, etc. Where evaporation takes place from pools, calcite, the crystallized form of calcium carbonate, may form. If the pool waters contain admixtures of clay, iron, and other impurities, concretionary masses consisting of concentric

A SCENE IN THE UNDERGROUND CATHEDRAL

Besides the two exquisitely carved pilasters at the left, the ceiling and the floor are closely studded with many colored small secondary formations, the work of percolating underground waters of past centuries. This palace is one of the most richly decorated chambers of the Endless Caverns.

layers of material may be observed on the cavern floor after the water has evaporated as noted on page 37.

Where the bicarbonate water enters the cavern from enlarged crevices in the wall or ceiling "flowstone" is apt to appear. It resembles cascades of stone with smooth and rough surfaces. It also occurs in places over and about the foot of many columns, draperies and other secondary effects as noted on pages 20 and 21. The flowstone is so compact that grottoes or small caves are formed behind or beneath such a curtain.

One of the most fascinating exhibits in the Endless Caverns is the Diamond Lake. Here the pure calcite crystals with their three glittering faces appear about the margins of the lake; they also occur in clusters about the small columns which stand in the lake. These "diamond" anklets which surround each of the columns at the water level, also above and below this line, are attributed to the crystal development that goes on as the level of the lake rises and falls with the seasonal fluctuations in the amount of carbonated water present. Following the thaw of the winter snows and the appearance of the spring rains the water is apt to attain its highest level; while during the long summer months it slowly evaporates until the lowest level is reached. The numerous translucent stalac-

"LILY PADS"

The "Lily Pads" constitute one of the curious formations on the cavern floor. At the time the author visited them they were dry. Some others were filled with water. The corrugated margins of each of the separate basins were formed by the evaporation of the carbon dioxide and the precipitation of a film of lime at the moment the acidulated waters flowed over the upper edge of the embankment.

tites which abound above this lake and in the adjacent Palace of the Fairies are also composed of calcite, the purest form of calcium carbonate. These pencil-like tubes are hollow; the water that occasionally trickles through them to the lake is as pure and transparent as the "diamonds."

In the Endless Caverns the air has the temperature of fifty-six degrees summer and winter. In the summer season this air is derived from the currents which pour in through the crevices and sink-holes above the cavern. It is cooled in the numerous chambers through which it slowly moves, being on the average some days in its journey and finally escapes at the lower vents of the cave. When the temperature of the outer atmosphere is low, the current is reversed; it enters then through the outlets of the underground streams and finds its exit as warm air, from the crevices and sink-holes in the uplands. In consequence of the slow passage of this air through the cool, dry caverns, where there is almost no decomposing organic matter, it acquires a remarkable purity, which in warm

CONCRETIONARY FORMATIONS

The concretionary masses that appear on the floor of the Endless Caverns, in a passageway leading to the Oriental Palace, are full of interest in that they were not seen elsewhere. This portion of the cavern floor is composed of a mixture of clay, iron, and lime. The rounded concretions are built up of concentric layers of this composite material.

countries is found only in the midst of great deserts.

The Work of Water Above Ground

The Shenandoah Valley owes its existence to the more rapid erosion by surface and underground streams of the limestones that lie in the Valley than of the resistant rocks that form the mountains flanking it on the two sides. The valley trends northeast-southwest, parallel with the bounding mountains and it varies in width from fifteen miles in the southwestern part along the James River divide to twenty-five in the latitude of Harpers Ferry on the Potomac River.

The general surface of the valley is that of a broad undulating plain which slopes from 2,000 feet above sea level on the James River divide northeastward to 400 feet at Harpers Ferry. The crests of the bordering mountains rise from 1,000 to 2,000 feet above the plain. In places the surface is broken by low rounded hills which rise 200 to 300 feet above it, or by low longitudinal ridges of gently subdued character. Between the latitudes of Strasburg and Harrisonburg, the picturesque Massanutten Mountains with crests reaching 2,500 feet above sea level divides the valley into two parts. The Endless Caverns are about in the center

SKYLAND

There are many chambers in the Endless Caverns, how many no one knows, for the end has not been reached. The scene here is of interest to a geologist for it exhibits in an attractive manner progressive stages in the development of the caverns. Natural joint-planes and bedding-planes in the limestone are prominently displayed in the lower central portion of the view. On the distant ceiling some of the intersecting joint-planes afford slow passage for the underground waters and the development of rows of stalactites. The columns and the drapery effects about the portal indicate an older and more mature seepage course for the ground waters.

of the more westerly of the two valleys.

The Shenandoah River system drains the valley. All of its important tributaries enter from the northwest; only small streams enter from the southeast along the Blue Ridge side. The chief tributaries which rise in the Alleghany Mountains flow east across the strike of the ridges through numerous water gaps. On reaching the foot of the Blue Ridge these tributaries join the Shenandoah, a more youthful stream, and turn abruptly in a northeasterly direction parallel with the strike of the rocks.

The fact that the trunk portion of the Shenandoah River is more youthful than its tributaries and flows in a different direction than they do is one of the striking episodes in the development of the Shenandoah Valley. This anomalous condition represents the work of a vigorous pirate stream which beheaded the former great rivers of the area and diverted their headwaters into its own channel.

The frequent incisions in the even crested mountain ridges known as wind gaps, but which were formerly water gaps,

THE HINDOO TEMPLE

The rooms in the Endless Caverns are not so large as some of the chambers in the Mammoth Cave, Kentucky, and the Carlsbad Cave, New Mexico, but no doubt the Virginia ones are more attractive to the visitor for their limits can be seen. They are all beautifully decorated with primary, secondary, and tertiary deposits and pleasing color effects. In this large room Nature has revealed not only her slow, untiring methods of work underground, but she has presented a pleasing ensemble of lines, columns, and mass effects.

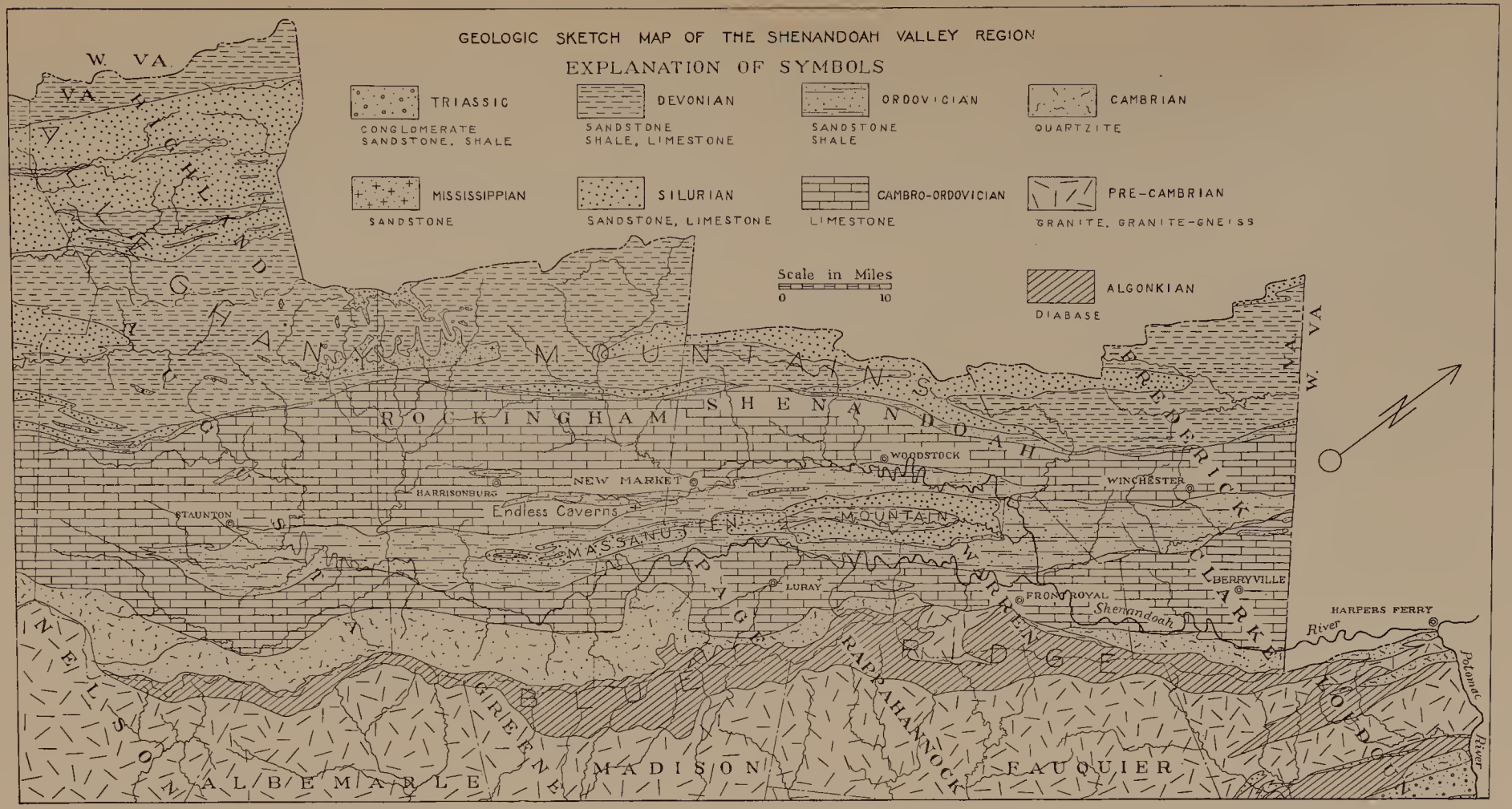
are mute monuments which bear witness of the former great strife that was waged periodically between the old and new river systems. The strife between these rivers was greater and more protracted than that between the armies of the North and the South, which fought on the same ground and for the same prize, the beautiful Shenandoah Valley, our Daughter of the Stars. All of the peculiar drainage features can be interpreted from the topographic and geologic maps of the region but as we motor through this deep set valley we are impressed more forcibly not only with the varying size and distribution of the many wind gaps in the Blue Ridge and Massanutten mountains but also with the relation of these gaps to the existing drainage lines. The conditions chiefly responsible for the concentration of the large number of eastward flowing streams into a single northeastward flowing river, the Shenandoah, are attributable to structure and the unequal resistance of the rocks to erosion, especially the difference between the lithologic types found in the Blue Ridge and the Great Valley. Only by starting with a condition of this sort can the present drainage and relief of the region be satisfactorily explained.

EXPLORERS SEEKING THE END OF THE ENDLESS CAVERNS

In January, 1925, the Endless Caverns attracted the attention of a number of explorers from the Explorers Club, New York. They penetrated for a considerable distance into the unexplored section beyond the "Diamond Lake." This view was taken alongside the "pipe organ" in the Grand Ball Room. Only a portion of the party is shown. From the left to right the men are Chester A. Reeds, Carveth Wells, Donald E. Rheutan, and George K. Cherrie.

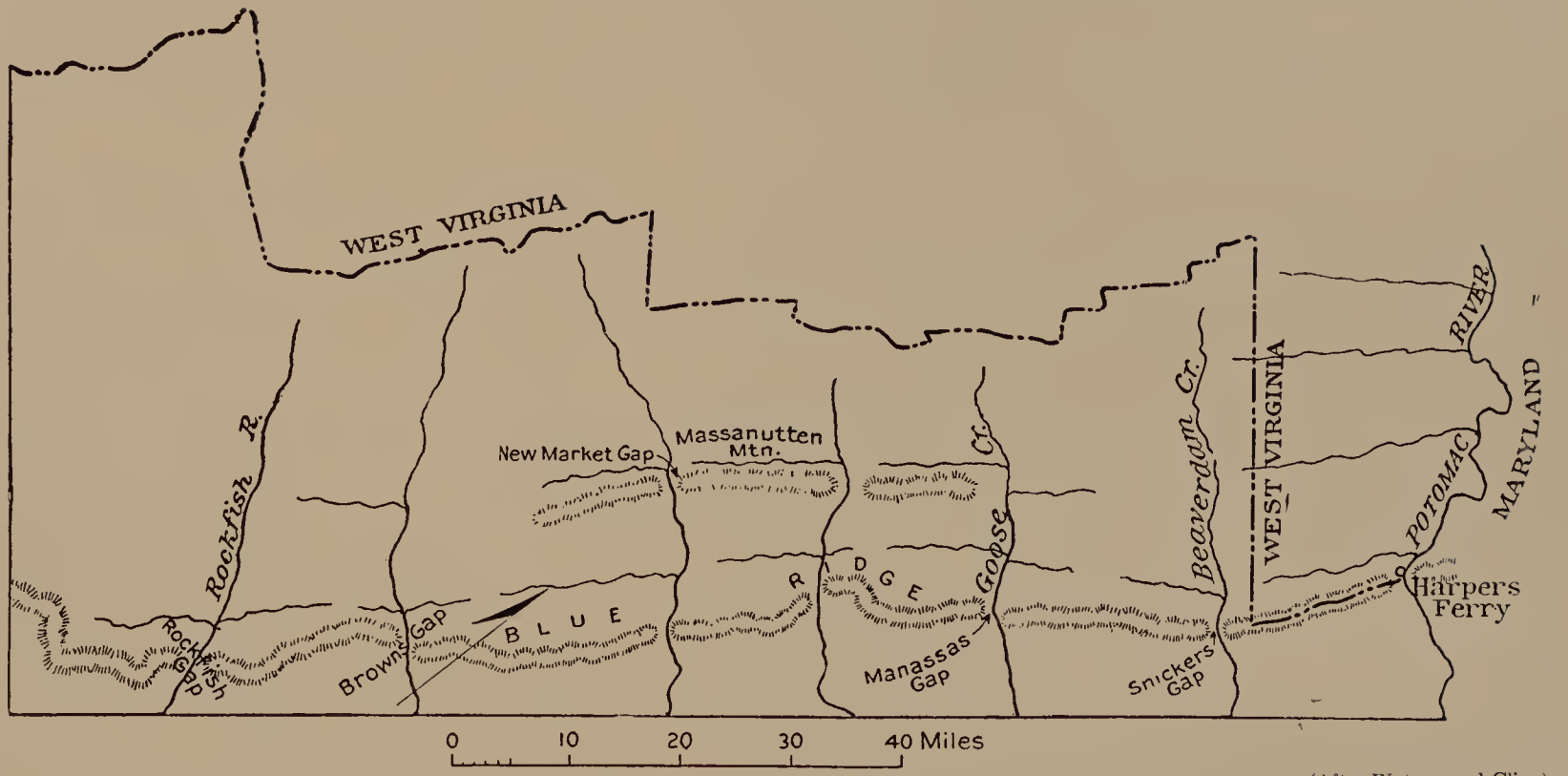
The thick series of sandstones, limestones, and shales forming these features were laid down practically in a horizontal position in a very ancient era of geologic time, some 150,000,000 years in length, known to geologists as the Paleozoic. The eastern margin of the basin or trough in which these sediments, particularly their lower members, were deposited, was in all probability considerably east of the Blue Ridge mountains. The uplift and folding of the sediments at the close of this long cycle of Paleozoic sedimentation resulted in reversing the drainage of the region from a northwesterly to a southeasterly direction. This marked the beginning of the oldest drainage systems of which we see evidence in the region to-day.

The uppermost members of this great folded series of Paleozoic sediments which now constitute the Alleghany mountains were of a resistant character, and must have completely covered the great Shenandoah limestone formation near the base of the section. By long erosion of these folded sediments, beds of different lithologic character were brought to the surface which varied widely in their ability to resist erosion. The final result was the almost entire removal of the sediments from the crest of the Blue Ridge, the



A GEOLOGICAL SKETCH MAP OF THE SHENANDOAH VALLEY.

Rocks of different ages and of varying degrees of hardness are to be found in and about this beautiful valley. The block patterns in the upper portion of the map, which represent various formations of rock, have been arranged in the order of geologic age, beginning with the youngest on the left and progressing down each column to the right. Originally the different beds of sedimentary rock were deposited horizontally one above the other in an arm of the sea which extended over the region. Subsequently, these same sediments were folded and uplifted into the Appalachian Mountains. Following repeated periods of uplift, the streams of the region attacked the folded rocks and wore away the soft shale and limestone beds more rapidly than the harder ones consisting of sandstone, granite and the like. The Endless Caverns and the great Shenandoah Valley have been carved out of the extensive Shenandoah limestone of Cambro-Ordovician age which occupies the central portion of the area.



(After Watson and Cline)

STREAMS OF THE SHENANDOAH VALLEY REGION DURING THE FIRST CYCLE OF EROSION.

From this map it may be noted that the seven rivers, beginning with the Rockfish River on the left, and ending with the Potomac River on the right, flowed southeast towards the sea across the Blue Ridge Mountains. The mountains were not high above sea level during this stage. The disposition of the tributaries at right angles to the main streams west of the Blue Ridge and the Massanutten Mountain suggest that these tributary streams already flowed on soft beds of rock, perhaps limestone which extended northeast and southwest, parallel with the trend of the mountains. The position of the tributary streams indicates that the two limestone valleys which we see to-day, separated by the Massanutten Mountain, had already begun to form. The main channels of the seven river systems crossed the mountain ridges through water gaps.

exposure of a great belt of Shenandoah limestone to the northwestward, and the Alleghany Ridges retaining their sandstones except where streams had cut down to the underlying limestone.

The streams flowing across the upturned strata subsequently found themselves working on beds of widely varying degrees of resistance in different parts of their courses. East of the Alleghany Ridges the chief resistant beds were the sandstones of Massanutten Mountain, the cherty beds of the Shenandoah limestone group, and the igneous rocks and Cambrian quartzite of the Blue Ridge. These were the chief and controlling barriers in the path of the southeast flowing streams. The largest streams were able to lower their channels across these barriers more rapidly than the smaller and less able-bodied ones. As a consequence, this gave the tributaries of the larger streams flowing over soft limestone beds an advantage over the tributaries of the smaller streams flowing at higher levels, and it was therefore only a matter of time till the tributaries of the large rivers had captured the smaller streams.

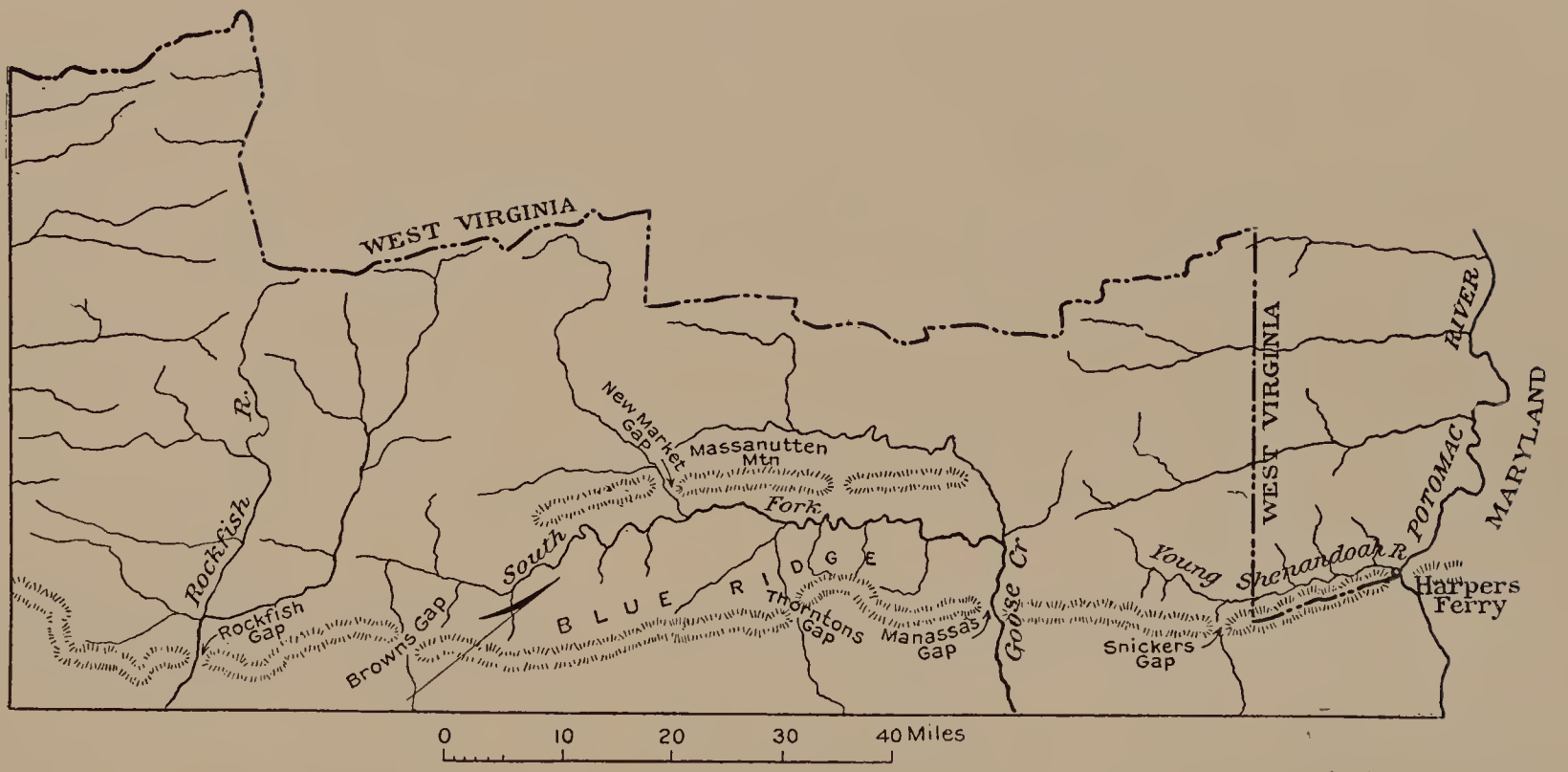
FOUR STAGES OF STREAM EROSION

The First Cycle — Four stages of stream erosion have been noted by geologists in the Shenandoah Valley region. The oldest and highest of these is represented to-day in the even crested ridges of the Blue Ridge, Massanutten Mountain and Alleghany Ridges. At the time of its development the region occupied a much lower position than now with reference to sea level and the entire landscape was reduced to a peneplain, or low seaward sloping surface, except for some minor areas in the Alleghany Ridges and Blue Ridge which remained as monadnocks or low hills reaching above the general level of the plain. As indicated by the large number of wind gaps in the Blue Ridge cut below the level of the former plain, the drainage conditions of the region varied but little during this stage.

The abundance of these gaps in the Blue Ridge shows with reasonable certainty that practically all of the streams maintained their seaward courses across the Shenandoah Valley area. This was doubtless due to the more or less uniform lithologic character of the rocks on which the streams were working. The overlying sandstone beds which covered the Shenandoah limestones were removed only in part during this cycle of erosion, and the soluble limestone rocks which now outcrop in the Valley district west of the Blue Ridge remained for the most part covered.

Second Cycle of Erosion.—Following the uplift of the region in Tertiary times, the streams were rejuvenated and they began to remove whatever formations covered the limestones of the Shenandoah Valley. The basaltic and granitic igneous rocks of the Blue Ridge and the resistant Cambrian quartzites which flank it on the northwest side offered serious resistance to the normal seaward course of the rivers. Due to the greater hardness of these rocks, drainage adjustments developed rapidly west of this mountain ridge and many stream captures occurred.

The first step in the interesting series of drainage changes which occurred in the early part of this second cycle of erosion was the capture of all small streams flowing through shallow gaps in the then low Blue Ridge by tributaries of the major streams. The distribution of the large and small wind gaps in the Blue Ridge argues strongly against capture of all these streams by the young Shenandoah one after another. On the contrary the early stages of the process resulted in the development of three drainage systems for the entire region. These have been named in order from north to south: (a)



(After Watson and Cline)

STREAMS OF THE SHENANDOAH VALLEY REGION DURING THE SECOND CYCLE OF EROSION.

The region was uplifted at the close of the First Cycle and the streams rejuvenated. As noted on this map only three main rivers cross the Blue Ridge, namely, Rockfish River, Goose Creek, and the Potomac. Their tributaries have grown headward and diverted the waters of four of the main streams of the previous stage into new channels. The former courses of these beheaded rivers are represented by wind gaps in the Blue Ridge as at Brown's Gap, Thornton's Gap, and Snicker's Gap. Only one stream continues across the Massanutten Mountain through the New Market Gap. The former water gap to the north is dry for a Goose Creek tributary has diverted the stream. The young Shenandoah River has already intercepted Beaverdam Creek opposite Snicker's Gap and diverted the water into the Potomac.

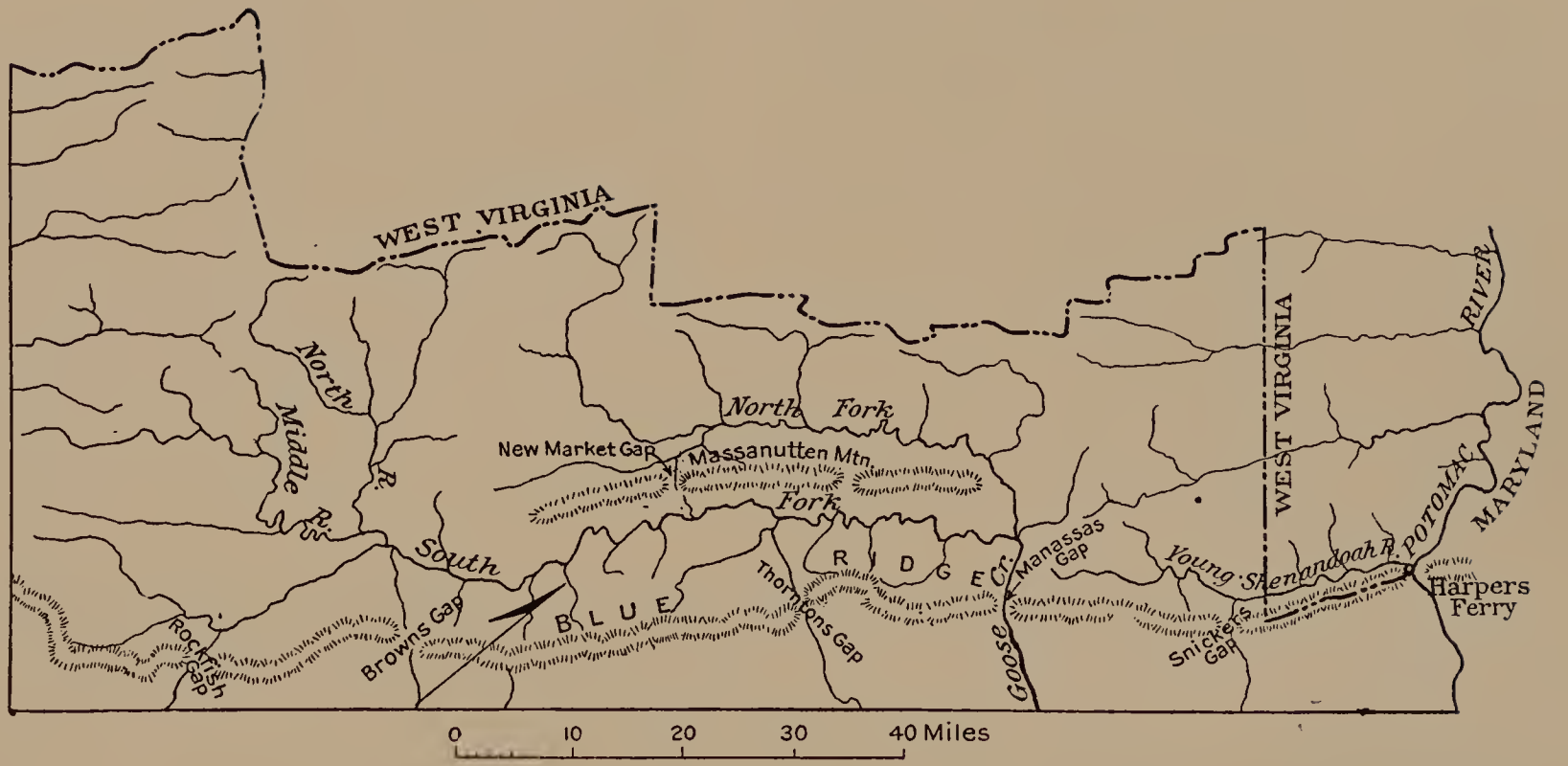
the Potomac, (b) Goose Creek, which once occupied Manassas Gap and (c) Rockfish, the stream which once occupied Rockfish Gap. The relative importance of wind gaps, including size, depth, and number, in the Blue Ridge, affords evidence that there was an intermediate stage between the original condition of drainage and this triple system, but the ultimate result was the three systems mentioned above.

Goose Creek which crossed the Blue Ridge through Manassas Gap opposite the town of Front Royal being more able bodied than neighboring streams lowered its channel across the Blue Ridge faster than the others, resulting in its tributaries capturing all the smaller streams in its vicinity both to the northeast and southwest.

The capture of North Fork by tributaries of Goose Creek affords the most interesting case of stream piracy in the region, and also shows the details of the process of stream capture and adjustment. North Fork entered the valley through Brock's Gap opposite Broadway and flowed across the valley, through New Market Gap in Massanutten Mountain, and thence across Page Valley, and the Blue Ridge through Thornton's Gap. A tributary of Goose Creek first intercepted North Fork on the east side of Massanutten Mountain near Luray, abandoning its course through Thornton's Gap it continued across Massanutten Mountain for a long period through the New Market Gap. While this was going on another tributary of Goose Creek headed west of Massanutten Mountain through Moreland's Gap in the most westerly ridge of the range, and following Little Fort Valley entered Goose Greek between Riverton and Strasburg. This stream intercepted North Fork on the west side of Massanutten Mountain and diverted its waters through Moreland's Gap. Later a third tributary of Goose Creek which entered it near Strasburg in a course close to the western foot of the mountain, again captured North Fork opposite Moreland's Gap and diverted the stream to its present course.

While the tributaries of Goose Creek were diverting the waters of various neighboring streams to Manassas Gap, similar captures were in progress in the southern part of the Shenandoah Valley opposite Rockfish Gap. As this gap is large it evidently was the outlet for the drainage of a large part of the valley between Port Republic and the divide between the Shenandoah and James rivers. Before the completion, however, of the second cycle of Tertiary age, the same tributary which captured North Fork near Luray worked its way southwestward to the vicinity of Waynesboro and captured the Rockfish system, diverting its waters northeastward through Manassas Gap.

Third Cycle of Erosion.—The previous stage of erosion was brought to a close by a second uplift of the region and a third cycle of erosion was inaugurated. It has been called the Shenandoah, for an extensive plain was developed on the Shenandoah Valley limestone during this cycle. During the early part of the Shenandoah stage the rival drainage systems were Goose Creek and the Potomac. The Potomac was the more able bodied stream because it was in all probability the larger of the two, and because the Blue Ridge at Harpers Ferry was, on account of width, a less effective barrier than Manassas Gap. During the latter part of the second cycle the young Shanandoah River, a tributary to the Potomac River, captured the headwaters of Beaver Dam Creek on the northwest side of the Blue Ridge at Snicker's Gap and possibly other small streams in the northern part of the valley. Following this adventure it extended its course



(After Watson and Cline)

MAP OF THE SHENANDOAH VALLEY REGION DURING THE THIRD CYCLE OF EROSION.

The region was uplifted again at the close of the Second Erosion Stage. On this map Rockfish River, one of the three principal river systems that drained the Shenandoah Valley during the second cycle, appears beheaded and its waters diverted into the South Fork of Goose Creek. The Rockfish water gap has become a wind gap. The river that flowed through the New Market Gap has also been intercepted and its waters turned into the North Fork. The young Shenandoah has grown headward and approached close to the main channel of Goose Creek.

(After Watson and Cline)

THE PRESENT DRAINAGE OF THE SHENANDOAH VALLEY

At the close of the third period of erosion the Shenandoah Valley plain was so well developed that the rivers assumed tortuous courses where they wandered over the level stretches. While the region was being gradually uplifted during the fourth stage, the rivers kept to their old meandering channels and have continued to do so. At the present time their channels appear about three hundred feet below the level of the Shenandoah plain. The valley thus consists of a rolling country set some fifteen hundred feet below the tops of the even crested mountains. Only one prominent stream capture occurred during the fourth stage, namely: the young and vigorous Shenandoah River worked headward far enough in the vicinity of Manassas Gap to divert the large Goose Creek system into its own channel. The story of the former drainage of the Shenandoah Valley region is told plainly by the numerous wind gaps in the Blue Ridge and Massanutten Mountain. The deepest, for example, Manassas Gap, are sought out by the highway engineer and the touring automobilist.

headward along the foot of the Blue Ridge and captured the entire Goose Creek system at Manassas Gap, diverting its waters to the Potomac. This was the last important capture in the development of the present Shenandoah system. A third uplift of the region brought the Shenandoah cycle to a close. During the latter part of this cycle there was some deposition of material in the form of gravels and sand derived from the neighboring mountains. This material is now found on well preserved but small remnants of the Shenandoah plain.

Fourth Cycle of Erosion.—A fourth or recent cycle of erosion has dissected the Shenandoah plain into an intaglio, and the streams are now flowing in U-shaped valleys some 300 feet below the old Shenandoah plain. Their present flood plains vary in width depending on local lithologic conditions. They may be as much as a mile in places, or they may be entirely absent. Temporary base levels are locally in process of development above resistant rock in the stream beds. Their U-shaped outlines have been inherited from the closing stages of the former cycle.

Drainage changes during the fourth or recent cycle have been insignificant and of comparatively minor importance. Those that have occurred are of the intercision type of piracy where incised meanders of two neighboring streams working on the opposite sides of a divide finally cut through and the larger stream, since it is flowing at a lower level, captures the waters of its neighbor. An interesting case of this kind has occurred in comparatively recent times at Bridgewater where Dry River has been intercepted a mile above its former mouth and drained into North River. Before the interception both streams were flowing in meandering courses, and each directed its current against opposite points in the ridge between them. This capture has been so recent that the two streams do not meet at grade and there is a small fall in Dry River a few yards above the junction. Another instance of this type of capture about to occur is near Mt. Crawford where North River is about to intercept another of its tributaries in the same manner about one mile above their present junction.

CONCLUSION

The foregoing discussion implies that the Endless Caverns and the Shenandoah Valley have endured for vast ages. The geologist looks upon the caverns, however, as evanescent, for their duration is brief when compared to the time consumed by the rivers in shaping the surface features of the landscape. The entrance to the Endless Caverns is some fifteen hundred feet below the towering crest of Massanutten Mountain. This difference in elevation represents the amount of rock that the North Fork and its tributary streams have removed from the region during three of the four periods of pronounced erosion outlined above. If all of the eroded material were restored above the Endless Caverns to the level of Massanutten Mountain we would find that the greater portion of the section would be composed of limestone, and that there would be room enough to place several series of caverns one above the other.

The present Endless Caverns have endured, no doubt, since the fourth or last cycle of erosion was inaugurated. During that interval the streams eroded their valleys 300 feet below the general level of the Shenandoah plain. As to how long a time it has taken the rivers to do this work we do not know, but obviously thousands and thousands of years, perhaps millions. At any rate science teaches us that the beautiful Endless Caverns, a fascinating handiwork of nature, were not made in a single day, but day by day throughout countless ages.

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